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EXPERIMENTAL STUDIES OF CRYSTAL-MELT DIFFERENTIATION IN PLANETARY BASALT COMPOSITIONS

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An important process that controls the evolution of magmas on and within planetary bodies is crystal-melt differentiation. One type of differentiation occurs through the removal of crystalline solids from residual melt by overgrowth zoning, which isolates the crystal interior from reaction with residual liquid. The process of differentiation which accompanies solidification leads to a variation in the composition of magmatic liquids, and contributes to the compositional diversity observed in igneous rocks. It is the dynamic behavior at crystal-liquid interfaces in a solidifying magmatic system that controls the efficiency of this differentiation process.

Experimental studies of silicate melt solidification have been carried out on several planetary and terrestrial melt compositions, and experiments on one of these compositions in the microgravity environment of the Space Station would provide a unique opportunity to understand the factors that control crystal growth and crystal-melt exchange processes at crystal-melt interfaces during solidification. As a crystal-melt interface advances during solidification, diffusion and convection are the two dominant mechanisms by which heat and mass are transferred away from the interface into the advancing liquid. In crystallizing silicate melt systems, convection in crystal-melt aggregates in the vicinity of the crystal-melt interface is generally thought to have only a small effect, but its contribution is unknown. If convection is important, it will homogenize the residual liquid and increase the efficiency of differentiation in residual liquid that can be caused during overgrowth zoning. In the absence of convection, heat conduction away from the crystal-melt interface may become an important factor in controlling the stability and development of the interface. Under microgravity conditions, crystallization can be carried out in an environment where the convective contribution can be diminished, and the diffusive contributions become the dominant controls.

Experimental Requirements:

The experiments would use a chemical system that is thoroughly studied under terrestrial gravity conditions (e.g., Apollo 15 quartz-normative basalts) and redo a selected set of controlled cooling rate experiments in microgravity. These experiments require a furnace similar to the Williams/Lofgren design (see Williams, A System for Conducting. . .This report) which provides the capability to carry out programmed cooling rate experiments under controlled oxygen fugacity conditions. It would also be desirable to have a furnace capable of processing larger volumes of silicate material, up to 50 grams, under controlled cooling rate and controlled oxygen fugacity conditions. This large volume capability would allow study of size-scaling effects of sample surface area and sample volume to nucleation and growth behavior. Again, the microgravity environment provides a unique opportunity to study this effect, since crystals and liquids can be kept from separating by gravity-induced crystal settling. An idea of the magnitude of the effect of changes in the sample volume to surface area ratio on the crystal growth and nucleation behavior is desirable, since the growth rates determined in these experiments are applied to natural magmatic systems which are characterized by large volume to surface area ratios.

The experiments would range from several hours to 50-75 hours in duration, and total experiment time could approach 350 hours. About 20 experiments are required. The experiments would initially be positioned using FePt alloy loops. An extension of the experiment would be application of acoustic positioning techniques. Another desirable modification would be a rotating furnace or experimental charge to counteract even microgravitational effects on crystal-liquid settling over the long durations required for the experiments.

The possibility for on-site examination of some or each experimental charge is desirable. Examination would require the preparation of a thin section or polished surface which would be observed by optical microscopy and scanning electron microscope techniques (an EDS attachment would be desirable). The possibility for on-site examination would optimize planning of succeeding experiments.